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CBRNE DETECTION: TECHNOLOGY IS NOT A STRATEGY

BY

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CBRNE DETECTION: TECHNOLOGY IS NOT A STRATEGY

by

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ABSTRACT

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Advances in science and engineering have put sophisticated Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) detection devices onto the battlefield. While it is tempting to allow new technology to replace older forms of CBRNE surveillance, detectors have inherent weaknesses that can be exploited by opponents. The Department of Defense should review its strategy for CBRNE agent surveillance, beginning with control of the confirmatory process in the acquisition and development of new technology, in the development of doctrine, and in deployable laboratory operations.

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> "As it turned out, no Iraqi chemical attacks of any consequence took place during Operation Desert Storm, but low-level exposures to chemical fallout may have occurred. One indication was provided by the M8 portable automatic chemical agent alarms, which were deployed upwind of U.S. units and continually monitored the atmosphere for blister and nerve agents. Throughout the air and ground campaigns, thousands of M8 alarms went off across the battlefield--so many, in fact, that troops started disabling them so that they could get some sleep."
>
> – Jonathan B. Tucker

Since Operation Desert Storm, advances in science and engineering have put ever lighter and more sophisticated means of detecting Chemical, Biological, Radiological Nuclear and Explosive (CBRNE) agents into the hands of strategic corporals[1]. It works—to a degree. But while it is tempting to believe that the Department of Defense's investment in detection systems will provide military commanders with an immediate and perfect answer, that hope is a mirage.

Automated detectors are constrained by the laws of probability: the larger the number of potential options, the harder it is to predict which one will be needed. Any detector can be foiled by new agents or new circumstances, and in addition to an expanding list of CBRNE weapons, the modern battlefield increasingly contains significant non-weaponized health threats. Advances in on-site detection technology do not replace the need for other forms of surveillance, including confirmatory laboratory analysis.

Department of Defense (DOD) doctrine, particularly the multiservice field manuals for CBRNE, frequently refers to deployable medical laboratories and their role in confirming Weapon of Mass Destruction (WMD) threats. The DOD has at least 8 different types of deployable units with a mission to provide “field confirmatory” testing of threat agents[2]. Most are medical units, ranging in capability from the Air Force Biological Augmentation Team (BAT), a 2-person team equipped with a portable device that can identify organism nucleic acids, to the Army’s Area Medical Laboratory, which has an integrated suite of laboratory instrumentation and 43 scientists and technicians.

These units have rarely deployed in recent years, and a lack of attention to their structure, function and deployment is creating a widening fissure between the detection and confirmation of potential threats. Field medical laboratories have an impressive history and tradition, but they are not keeping up with military transformation. The analysis that follows suggests why and how the DOD should revise its deployable confirmatory laboratory capacity to reflect current and future requirements.

Detect, Protect and Confirm

Until recently, automated detectors have been a relatively minor aspect of CBRNE hazard identification. The more traditional method has been medical surveillance, including illness rates or symptoms in deployed forces, environmental findings reported by preventive medicine detachments, and medical intelligence reporting. Confirmatory laboratories are fundamental to medical surveillance[3], in part because they are the institutional repository for objective laboratory data about a geographic region. Through the analysis of submitted specimens, the scientific staff forms an objective picture of what is normal and abnormal for the area. Medical surveillance has the benefit of detecting all health hazards, not just WMD, but it can be slow.

Detectors like the M22 Automatic Chemical Agent Detection System or Joint Portal Shield are owned by commanders, immediately provide a reassuringly decisive yes/no result, and are accurate most of the time, all of which are useful attributes during a WMD attack. Especially in the absence of WMD threats, it can be tempting to rely on detectors at the expense of traditional medical surveillance, but automated detectors have inherent vulnerabilities. A primary weakness is that detectors are able to detect only what they are designed to detect, generally a short list of agents. Also, in past wars, the operational effect of chemical agents dramatically declined as force protection technology caught up with the threat.[4] For that reason, and given the history of chemical and biological warfare, it is reasonable to predict that both chemical and biologic warfare agents will continue to evolve as opponents strive for strategic surprise.[5] The Soviet biowarfare program made rapid progress during the second half of this century in creating new weaponized biological agents, training a generation of 'bio-weaponeers' in the process, some of which have taken their skills to countries not aligned with the US.[6] In addition, it is technologically difficult to differentiate between threat and non-threat bacteria[7], so there are few available biologic agent detectors compared to the number of threat organisms. Detectors can also be limited by the physical state of the agent, such as liquid versus gas. Finally, because detectors are designed to err in the direction of being too sensitive (falsely positive) rather than too specific (falsely negative), it is easy to be lulled into a sense of complacency by repeated false alarms, as exampled in the opening scenario of this paper.

The Chemical Corps developed automated detectors as an operational tool to detect gas attacks, not as a surveillance method. In another words, the goal was to provide a timely warning, because the identity of the agent was generally not important in making the decision to don protective gear. That paradigm has changed, and so has the battlefield. Civilian exposure to threat agents has become more likely, and because civilians lack protective equipment, issues related to their exposure may require decisions by commanders. Because detectors can identify a range of agent types, confirmation is necessary before making follow-on operational decisions. Radiologic and biologic agents are more likely to be used as weapons, which have effects that are not immediately evident. As automated detection equipment has improved, it has evolved into another form of surveillance. Like traditional medical surveillance, advanced detection devices will yield a mixture of true and false positive results. If not supported by analytical testing, the Combatant Commander is reduced to the current procedure for determining if masks can be removed…by having a soldier remove his mask[8].

Perhaps because the medical community has not been as active as it could be in the development and acquisition process for detectors, not enough thought has been given to the surveillance oversight needed to confirm or deny the screening result of automated detectors. The DOD national laboratories are well established as the gold standard for testing, but they are primarily research institutions and are not in the business of routine confirmatory testing. Doctrinally, medical laboratories seem to have been given the mission almost as an afterthought. Combat support hospitals and navy hospital ships should not risk contaminating their patient care mission by accepting WMD specimens in their laboratories, nor are they well-equipped to perform confirmatory testing for CBRNE agents. Other medical units with laboratory equipment vary widely in their capability. In practice the connection is even more lacking. As an example, at an overseas location employing the Joint Portal Shield to detect aerosolized threats, the author interviewed a technician assigned to maintain the equipment. Standard operating procedure upon a presumptive positive result was to immediately repeat the test. If the test result was positive again, the sample was shipped out of theater for definitive testing—hardly a timely way to confirm a positive result.

Structure and oversight of surveillance

DOD medical laboratory capability can be divided into three categories: relatively simple laboratories such as those embedded in troop medical clinics that are focused on support to diagnosis and treatment of individual soldiers; more advanced laboratories that support a variety of specimen sources and which serve a regional or specialty purpose; and national laboratories which serve as the gold standard for definitive identification and characterization of agents and conduct special studies and research. Much of this laboratory infrastructure was created during WWII, and at that time was overseen by a laboratory director in the Army's Office of the Surgeon General.

The Army deployed medical field laboratories in World War (WW) I and II, the Korean War, Vietnam, Bosnia and Iraq.[9] In most instances, the deployed units were designed as strategic assets, serving on a regional basis as a confirmatory laboratory for a range of missions including clinical pathology, general laboratory oversight, public health, environmental health and toxicology.[10] At the height of WW II, there were 19 field medical laboratories compared to approximately 600 clinical laboratories embedded in various patient care facilities overseas.[11] Currently, the Army has two Area

Medical Laboratories (AMLs) that are descendants of the WWII field medical laboratories, and approximately 400 deployable patient care facilities. [12]

Today there is no centralized military oversight of medical laboratories like there was in the 1940s. Instead, civilian organizations such as the Commission on Inspection and Accreditation of the College of American Pathologists regulate military clinic laboratories in the US[13]. FORSCOM medical laboratories have no equivalent oversight requirement[14]. The national DOD laboratories such as the US Army Medical Research Institute of Infectious Diseases (USAMRIID) and the US Army Medical Research Institute of Chemical Defense (USAMRICD) set the standards and protocols for testing. As research and development laboratories, they do not have external oversight per se, but have internal requirements for quality control which include external review standards such as the International Organization for Standardization (ISO).

Until 1999, roughly the same organization and oversight situation was true for civilian public health laboratories in the US. The Centers for Disease Control and Prevention (CDC) had the lead federal role in health surveillance for the US, and it relied upon reporting from local and state laboratories, which were funded and regulated by state or local authorities. After 1999, following Presidential Decision Directive 39, officials at the CDC, Association of Public Health Laboratories, Federal Bureau of Investigation, and USAMRIID established the Laboratory Response Network (LRN).[15] The LRN mission is “to maintain an integrated national and international network of laboratories that are fully equipped to respond quickly to acts of chemical or biological terrorism, emerging infectious diseases, and other public health threats and emergencies”.[16]

The LRN has 140 medical, veterinary, agricultural, and public health confirmatory laboratories for biologic agents and 41 chemical 'level 2' laboratories, which follow tightly prescribed protocols for standardizing laboratory equipment, training, analytical protocols and applying rigorous quality assurance programs for their member laboratories.[17] The LRN has plans to expand the program to include environmental sampling in partnership with the Environmental Protection Agency.[18]

A significant aspect of the LRN is that the confirmatory process is tightly controlled by CDC, to include laboratory proficiency, legal documentation, and release of laboratory results. The on-site reference laboratory confirms the result and forwards that information by secure communication to the CDC. The CDC, in turn, makes a decision to perform further tests or release the information immediately. In effect, this degree of control defines the meaning of a confirmatory result for the LRN, because it is not an LRN positive result unless it is performed by an LRN-certified laboratory technician, on a LRN-approved instrument, using an LRN protocol with LRN reagents, and reported by the CDC.

This is in contrast with DOD doctrine, which has little guidance on the release of non-patient-related laboratory information, and which defines confirmation much more loosely as "identification of a suspect BW agent by means of devices, materials, or technologies that detect biomarkers using two or more independent biomarker results[19]", and has no process for oversight. This explains why the configuration varies so widely in existing DOD deployable "field confirmatory" units. The Air Force BAT team meets this definition by carrying one piece of equipment, the Joint Biological Agent Identification and Diagnostic System (JBAIDS). The JBAIDS compares specimen nucleic acid sequences against an internal software library of agents, and is capable of detecting two independent biomarker results, but it cannot differentiate between a sample containing a few dead spores of naturally occurring anthrax and a sample containing viable weaponized anthrax. To an operational planner, the confirmatory capability looks the same, but to the end user, the commander on the ground, the difference is significant.

Laboratory analysis can be described as having degrees of confidence: for example, a confidence level of 95% means that 5% of the time, the result is wrong. A commander might be willing to make a decision to have his troops don MOPP 4 given a 70% confidence in a chemical alarm's accuracy, but the same commander might want the highest available level of confidence, such as provided by a national laboratory, before telling the international media that his military foe used a certain chemical agent on US forces. Between those two extremes, a field confirmatory laboratory can provide timely scientific analysis, technical advice and documentation to support a range of operational risk management decisions. It should also be able to clearly describe its degree of confidence in the result.

<u>OIF and organizational changes</u>

Prior to 2003, the DOD did not realize that it needed the capability to seize, exploit and eliminate a nation's WMD capability. That changed when one of the main objectives of the Operation Iraqi Freedom (OIF) campaign became identifying and eliminating Iraq's WMDs. The Expeditionary Task Force -75 was an ad hoc organization that was formed, equipped and trained over the course of several months and then deployed to Iraq to accomplish that mission[20]. The XTF-75 included two laboratories for analyzing WMD materials, one British and one American. Samples included nerve agent rounds, mustard shells, and a wide range of dangerous chemical substances[21].

Based upon this experience, FORSCOM activated the 20th Support Command (SUPCOM) (CBRNE) in 2004 with the intent of providing overall command and control to specialized CBRNE operations across the full spectrum of operations, as well as establishing a primary Army force provider for these capabilities. The 2006 Quadrennial Defense Review expanded the 20th SUPCOM's mission to serve as a Joint Task Force to command WMD elimination and site exploitation missions[22]. The mission of the 20th SUPCOM is "To deploy and conduct operations in support of combatant commanders (CCDRs) or other government agencies (OGAs) to counter CBRNE and WMD threats, in support of national combating WMD objectives. Its core focus is on tactical, operational, and strategic exploitation and elimination operations"[23].

The 20th SUPCOM's technical expertise (primarily explosive ordnance disposal and chemical technical escort units) is currently organized into the modular teams of WMD Coordination Element, Nuclear Disablement Team, and CBRNE Analytical and Remediation Activity (CARA). The CARA has a mobile analytical laboratory section, staffed primarily with Department of Army Civilian (DAC) scientists and technicians, as well as two remediation response sections and an aviation section.

The 520th Theater Army Medical Laboratory (TAML) was one of the earliest medical units to deploy into Iraq, in March 2003. It was located on Tallil Air Force Base with a mission to provide confirmatory analysis of chemical and biological warfare agents, and the TAML was used to confirm the results of the first operational use of Biological Integrated Detection System (BIDS) and the Joint Portal Shield Biological

Detection System[24]. The TAML quickly found itself involved in the laboratory aspects of a medical investigation as well, when arriving military forces became infected with Leishmaniasis from the numerous sand flies[25]. After re-deployment, Force Development, Office of the Surgeon General completed a planned conversion of the 520th TAML into two smaller units, the 1st and 9th Area Medical Laboratories, as a part of the Army's Medical Reengineering Initiative and in an effort to make a more modular and deployable asset.

The need for laboratory analysis in an overseas theater of operations has changed over the last several decades. After the 1991 Persian Gulf War, and the subsequent 'Gulf War Syndrome' the federal government increased efforts to identify and document occupational and environmental hazards during deployments[26]. Despite the lack of WMD used against US troops, some believe there is an increasing threat of WMD use[27], based upon a diaspora of Soviet biowarfare scientists who have immigrated to other countries[28] and the fact that non-state actors have successfully used CBRNE agents in bio-terrorism attacks[29]. If WMD agents are used, a theater laboratory will be needed to rapidly confirm if a known agent was used, even if at very low concentrations. Further, it will need to provide an internationally credible standard of documentation. If a new agent is used, the laboratory will be needed to get a "quick fix" on the identity of the agent and safely transfer adequate samples across international boundaries to the US national laboratories for definitive identification. Currently in Iraq, chemists are performing forensic analysis of explosive devices at the Combined Explosive Exploitation Cell (CEXC) to determine type, origin and ownership of explosives and provide the documentation to allow prosecution of those responsible for them as well as allow safe demolition of the weapons[30]. Additionally, just like in 2003, there will always be traditional health hazards that will need investigation and documentation, whether they affect forces immediately or cause delayed or chronic illness in veterans.

These missions encompass traditional medical and non-medical disciplines, and so should future deployable laboratory units. Although long-standing, there is nothing sacred about the division between medical and non-medical laboratory support. Rather, it is a remnant of the division of labor between the DOD institutions created during WWII in response to offensive chemical and biological weapons programs. With today's imperative for lighter and more deployable forces, not to mention the logistical and resource burden of maintaining a laboratory, it makes sense to serve the missions of force health protection, forensics and WMD elimination with one theater asset, especially where instrumentation and scientific disciplines converge. But deployed laboratory units must carefully work within the skill and protocol limitations imposed by their rapid personnel turnover in scientific personnel and the physical challenges to instrumentation that are inherent in a field environment. Each deployment needs to tailor the instrumentation and logistical support requirement to meet the specific theater requirements for information within the categories of CBRNE agents and occupational and environmental health threats with the smallest possible weight and size.

<u>From here to there</u>

The DOD's WMD defense system is weak due to the lack of integration of its confirmation capability. Advances in detection devices have emphasized instead of erased this weakness; in some ways the bureaucratic effort required to gain funding for the development and acquisition of technology has disguised the gap between detection and confirmation. The DOD should repair this deficit, and the crucial element is control over the confirmatory process at all levels: in the acquisition and development of new technology, in the development of doctrine, and especially at the operational level, in the use of standardized protocols and oversight.

While the LRN has much about it to admire, it should not become the DOD's standard. The needs of a well-protected fighting force facing a potential opponent armed with CBRNE agents is different than the needs of the US civilian population facing the potential of bioterrorism. The LRN's prescribed list of protocols and reagents speeds diagnosis and prevents faulty or premature information release, but also limits the range of confirmation capability — a suitable procedure given that the US national laboratories are close at hand, but overly limiting for overseas laboratories supporting the combatant commanders.

The exception is for DOD laboratory units having a Homeland Security mission, for example the CONUS military medical centers and the National Guard's Civil Support Teams-WMD. These units are supporting the Department of Health and Human Services (HHS) as the lead federal agency, and should follow the CDC's testing and reporting protocols to properly support that mission. Fifteen DOD laboratories in fixed facilities have already joined the LRN as biologic reference laboratories,[31] and the CST-WMD use their respective LRN-certified state laboratories as their higher level confirmatory laboratory.

Overseas confirmatory laboratories supporting DOD in a Title 10 capacity should not be constrained by LRN protocols, because they are not supporting HHS. Instead, the DOD needs to create an analogous system of oversight of laboratory capability, training, analytical protocols and proficiency standards that directly supports the Combatant Commander in making timely operational decisions requiring a relatively high degree of analysis. Examples of decisions that deployable laboratories should be supporting include when to remove protective gear; issuing guidance on exposure to toxic substances in the area of operations; supporting forensic requirements during sensitive site exploitation; and issues relating to the impact of hazardous agents on civilian populations.

In 2004, a committee of the Institute of Medicine (IOM) and the National Research Council (NRC) presented their recommendations to the Secretary of Defense on accelerating the research, development and acquisition of medical countermeasures against biologic warfare agents. One of the key findings was that the DOD internal organization was too disjointed to efficiently produce medical biodefense countermeasures such as vaccines due to the complex scientific and regulatory challenges involved, and the committee recommended the creation of a new Medical Biodefense Agency to solve that problem.[32]

What the IOM/NRC committee describes as disjointed organizational structure is a reflection of the organizational histories of the various commands. The laboratories involved in CBRNE agent research are located within DOD Health Affairs (Armed Forces Radiobiology Research Institute), the Army's Medical Research and Materiel Command (USAMRIID, USAMRICD and the Walter Reed Army Institute of Research (WRAIR)), US Army Medical Command (US Army Center for Health Promotion and Preventive Medicine), US Army Research Development and Engineering Command

(Edgewood Chemical and Biologic Center (ECBC)), the Defense Threat Reduction Agency, and the Defense Advanced Research Projects Agency. Understandably, each of these institutions has a different focus that defines it, which has probably contributed to a lack of progress in areas that cross disciplines.

One DOD organization should have responsibility for the oversight of scientific input to WMD laboratory confirmation operations, doctrine and technology acquisition. The Joint Requirements Office for CBRN Defense would seem to have this responsibility, as it has the mission to plan, coordinate and oversee joint CBRN defense operational requirements[33]; but it does not have the assigned scientific staff to perform this work directly. The skill sets need to design and implement CBRNE agent surveillance in a battlefield environment cross multiple medical and non-medical disciplines, and the expertise is divided amongst the institutions listed above. For example, the ECBC mission has focused on chemical weapon systems since 1970[34], while USAMRIID, USAMRICD and WRAIR are dominated by patient care missions and FDA regulatory requirements. The new Medical Biodefense Agency as envisioned by the IOM/NRC committee is also insufficient to address the comprehensive reform needed for operational WMD surveillance because the new agency would not span all the necessary disciplines. Either alternative might take on the role if properly resourced, or perhaps could direct a collaborative effort across the DOD national laboratories to assume this responsibility on a permanent basis. A less effective alternative might be some sort of standing committee of experts from each of the institutions.

To properly support the combatant commanders, confirmatory laboratories must be able to withstand international scientific scrutiny. US military intervention will likely involve coalition forces, and US actions abroad will be judged by international audiences both in the popular media and in the scientific community. There is no reason to support confirmatory laboratory assets of any type in a theater of operations unless it is credible and reliable in the eyes of the international scientific community. A field laboratory will obviously not have the same capability as a definitive laboratory in the US such as USAMRIID, yet for the analytical protocols it performs, the deployed laboratory must be able to demonstrate and document technical proficiency to an international analytical laboratory standard. In the meantime, DOD should actively support collaboration efforts such as the Canada, UK, US Chemical Biological and Radiological Memorandum of Understanding to standardize laboratory standards of equipment, training, analytical protocols and quality assurance[35]. The MOU was created to support standard CBRNE interoperability between the three nations and the analytical task force deserves active DOD support and encouragement.

In a 2001 force structure analysis, the General Accounting Office recommended the Army have three area medical laboratories.[36] It seems logical to expand that number to five, to allow alignment with one to AFRICOM, CENTCOM, EUCOM, PACOM and SOUTHCOM. In 1945, deployed medical laboratories were slightly over 3% of the total of overseas patient care units, which would equate to 12 units today if a similar ratio was used.[37] In comparison, the LRN has 140 reference laboratories in the US and estimates 98% of the US population is within 100 miles of an LRN laboratory.[38] Even though neither of the Army's two Area Medical Laboratories have been deployed since 2003, there is good argument for their expansion.

The existing AMLs should be revised to make them more useful to the Combatant Commanders. Some of this change has already begun, starting with a 2008 revision of the AML mission to include non-medical laboratory analysis. This needs to be quickly followed by a technical equipment review and revision, which has not been performed since the 2003 deployment. In addition, FORSCOM is in the process of modifying the command and control of the AMLs to place them under the administrative control (ADCON) of the 20th SUPCOM, while remaining a subordinate command of the 44th MEDCOM. This will likely result in AML deployment in support of 20th SUPCOM's missions in CENTCOM and will help hone AML core competencies by virtue of experience. In the meantime, units without a primary laboratory mission but that have 'confirmatory' instrumentation should be assessed to see if DOD should continue to resource that capability.

As made apparent by their lack of deployment, dividing the 520th TAML into two AMLs did not have the desired effect of causing them to deploy more frequently, but it did increase the overall administrative burden for maintaining the capability. This change should be reversed, and derivative Unit Identification Codes (UICs) used to deploy tailored teams instead.

FORSCOM should begin deploying the confirmatory laboratory capability it already owns, the sooner the better. The tinkering necessary to conceive and birth the proper amount of laboratory support will only come through practical experience. Even though the threat is not imminent, the amount of money DOD has spent on detection suggests that the threat is real, and best dealt with proactively. While the number of nations likely to use WMD against the US is decreasing or at least not increasing, the number of non-state actors with significant financial and technological resources for bioterrorism is increasing[39]. Non-state actors and terrorists engaged in asymmetrical warfare are more likely to use unconventional weapons like CBRNE agents. They will likely practice with an agent before using it against an enemy, and that will probably occur away from the scrutiny of the US homeland. Laboratories operating in overseas theaters can accumulate knowledge of existing conditions in the theater and be in a position to identify and investigate unusual circumstances. Two locations that should be considered for effective laboratory deployment are CENTCOM and Korea. In CENTCOM, a robust laboratory capability should be deployed to support on-going explosives analysis and force health protection issues. Korea does not currently have sufficient laboratory assets for CBRNE surveillance and would benefit from FORSCOM support of this mission.

Confirmatory laboratories are needed in the DOD's deployable inventory. Globalization will bring an increasing variety and frequency of health threats to impact future US military operations. The National Military Strategy predicts continued or increased US engagement in asymmetrical, expeditionary and contingency missions, often in failed states with reduced health infrastructure. Given the large investment DOD has made in CBRNE agent detection to meet this threat, it is only reasonable to make a proportional investment in its threat agent confirmation ability.

Regarding Mr. Tucker's excerpt at the beginning of this monograph, what could a deployed confirmatory laboratory have done to support the theater commander after the M8 alarm went off? Further air sampling could have pinpointed the source of the alarm, as well as other potential health threats. Air, water and soil could have been tested for agent breakdown products which would provide further evidence of cause, but which would not have been visible to the detectors. The laboratory could have provided solid evidence of low-level agent concentrations, or documented the artifact that set off the alarm and provided impetus for alarm re-design or guidance for standard operating policy for operating the alarm. For example, if diesel fumes were the source of the false alarms, the motor pool could have been re-located and the alarms could be put back into use. After re-deployment, laboratory documentation of the environmental conditions could protect the government from false claims of exposure and help support re-design of the detector.

Endnotes

[1] The term 'strategic corporal' was coined by General Krulak to describe the impact of decision-making by junior leaders in modern conflicts. General Charles C. Krulak, "The Strategic Corporal: Leadership in the Three Block War", Marines Magazine, January 1999, 5.

[2] Department of the Army, Chemical, Biological, Radiological, Nuclear, and High Yield Explosives Operational Headquarters, Field Manual Interim No. 3-90.10 (Washington, D.C.: US Department of the Army, 24 Jan 2008), E-1. Ibid., H-6

[3] S. M. Teutsch and R. E. Churchill, Principles and Practice of Public Health Surveillance, 2nd ed. (New York, N.Y.: Oxford University Press, 2000), 254.

[4] Jonathan B. Tucker, War of nerves: chemical warfare from World War I to Al-Qaeda (New York, N.Y.: Pantheon Books, 2006), 18.

[5] Ibid., and Ken Alibek with Stephen Handelman, Biohazard (New York, N.Y.: Random House, 1999), 259-261.

[6] Alibek, 271-275.

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